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Research Summary
Oil Spills

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Research Summary

Oil Spills

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This brochure is one of a series providing a brief description of major areas of the Environmental Protection Agency's research and development program. Comments as to how this summary could be improved are welcome. Please address your suggestions to:

Research Summary Editor
Office of Research and Development, RD-674
US EPA, Washington DC 20460

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16. ABSTRACT

This summary of EPA Office of Research and Development (ORD) research in the oil spills area discusses current and emerging spill control technologies, the ecological effects of petroleum, and ORD's approach to transferring information about its research program to the appropriate users.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
oil recovery oil refineries oil storage oil tankers oil wells oil fields oil emission muds	ecological effects of oil spills oil spill cleanup	6a, c, f, q, s,t 7c,d 8a,h,j 47a,d,f 48a,b 57a,d,f

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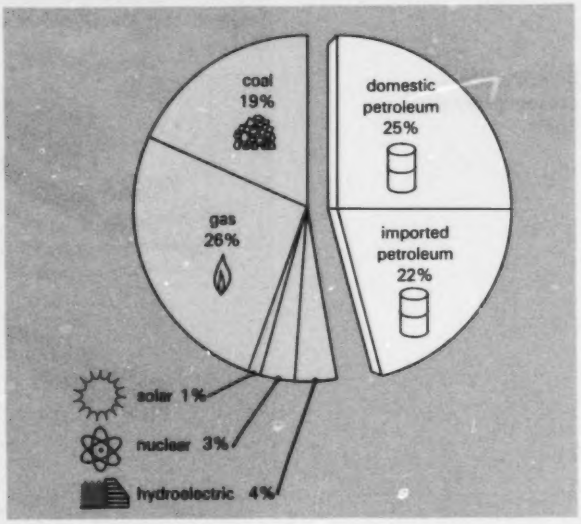
US Reliance on Oil

Nearly half of our total energy needs are met by petroleum, making it the largest direct source of energy in the United States. Large demand and a limited domestic supply have required us to import nearly one half of our oil at an annual cost of more than $30 billion. Demand has grown to the point that as of September 1978 we were importing an average of more than 240 million gallons of oil each day, predominately by ship.

As the world has learned in the last ten years, the transportation of petroleum involves significant elements of risk. The recent Amoco Cadiz tanker spill off the northern coast of France provided a disconcerting example of some of the possible severe impacts of oil on the environment.

US Energy Consumption by Source



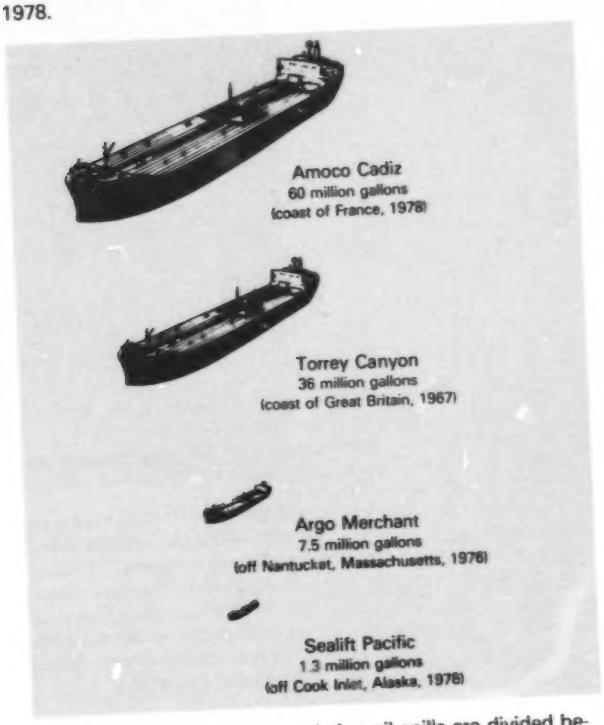
Major oil spills frequently result in extensive damage to plant and animal life, unsightly fouling of beaches and waterways, and great economic hardship for individuals and communities. In addition to the more familiar damages, petroleum and petroleum products have been shown to affect plant and animal growth patterns, decrease rates of photosynthesis, disrupt feeding and reproductive behavior, and seriously impair other vital biological processes.

The need for a cohesive Federal oil spills research program has become increasingly apparent in the aftermath of such major spills as the Santa Barbara, California offshore well blow-out of 1969, and the December 1976 grounding of the Argo Merchant near Nantucket, Massachusetts. Numerous agencies including the Environmental Protection Agency, National Oceanic and Atmospheric Administration, Coast Guard, and the Departments of Energy and Interior, are engaged in research projects directed toward preventing and minimizing the effects of spills. One major Federal initiative to

coordinate a portion of this research is the Interagency Energy/Environment R&D Program, sponsored by the Office of Research and Development (ORD) within the EPA. Through the Interagency Program alone nearly $4 million is being spent annually on oil spills-related research.

Oil spills research is also one of the aspects of ocean pollution research being considered by the Interagency Committee on Ocean Pollution Research and Development and Monitoring. The committee, chaired by the National Oceanic and Atmospheric Administration and composed of several Federal agencies including the EPA, is developing a five-year plan for a comprehensive marine pollution-related Federal program. This planning activity is mandated by the Ocean Pollution Research and Development and Monitoring Planning Act of 1978.

Relative Sizes of Representative Spills



Regulatory Responsibilities

Federal responsibilities for regulating oil spills are divided between the EPA and the Coast Guard under two broad areas: response and prevention. The EPA is charged with setting regulations for responses to inland spills, while the Coast Guard has responsibility for spills occurring in coastal waters and the Great Lakes. With regard to prevention, the EPA and the Coast Guard are responsible for non-transportation-related and transportation-related spills, respectively. To enable the EPA to fulfill its regulatory responsibilities, the Office of Research and

Development conducts a wide-ranging oil spills research program. Major initiatives are underway to:

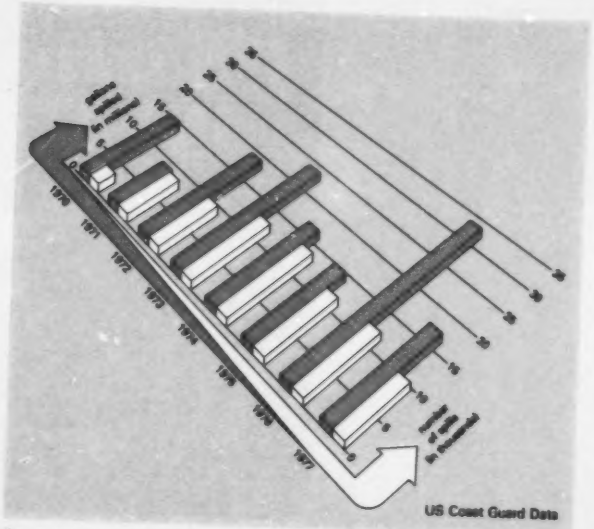
- develop oil spill prevention, control, cleanup, and monitoring methods and technologies to minimize adverse effects on the environment.
- improve our understanding of the impacts of spills on ecosystems and our capability to predict and assess the effects of petroleum on plants and animals.
- ensure the successful transfer of research information through technical reports, manuals, workshops, and other methods of information dissemination.

Spill Prevention Control, Cleanup, and Monitoring

Every year more than ten million gallons of oil escape into U.S. waters as a result of more than ten thousand spills. The National Oil and Hazardous Substances Pollution Contingency Plan, developed as a result of section 311 of the Federal Water Pollution Control Act, designates which local, state, or Federal organization is responsible for the cleanup of a given spill.

Upon request, ORD's Oil and Hazardous Materials Spills Team in Edison, New Jersey provides technical support to personnel responsible for spill cleanup by assisting in the control, removal, and recovery of petroleum and other hazardous substances. The team also obtains and analyzes samples of spilled material and compiles initial environmental impact data. A fully equipped mobile chemical laboratory was recently developed to facilitate rapid on-site analyses during spill decontamination and removal operations.

Oil Spills in US Waters 1970-1977



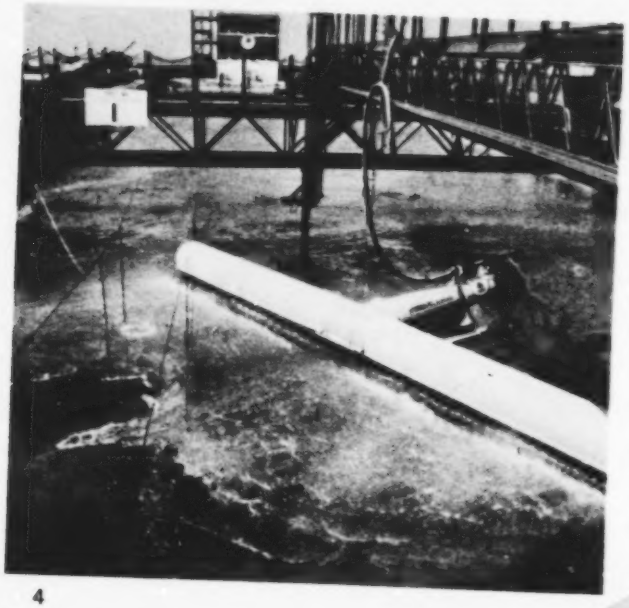
SPCC Plans

In December of 1973 the EPA announced oil pollution regulations requiring the preparation of a Spill Prevention, Control, and Countermeasure (SPCC) plan by the owner or operator of any facility that could reasonably be expected to spill oil into U.S. waters. To assist in the preparation of SPCC plans, ORD's Edison, New Jersey branch of the Cincinnati, Ohio Industrial Environmental Research Laboratory, is funding a study to determine the feasibility of technologies that could be used by operators of oil storage facilities to comply with these regulations.

Spill Cleanup Testing Facility

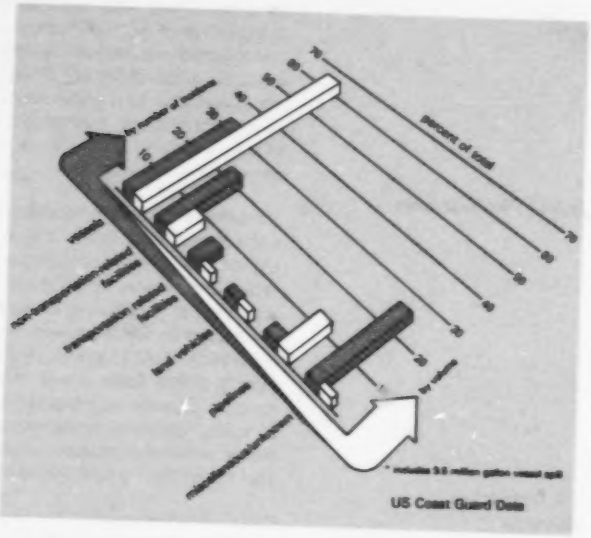
The EPA Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) facility is also operated by the Edison, New Jersey team, and permits environmentally safe testing of spill cleanup methods and technologies. The facility consists of a 2.6 million gallon concrete tank, with mobile bridges overhead capable of carrying monitoring instrumentation including closed circuit television. The facility has a wave generator and simulated beach available to help duplicate actual environmental conditions. The efficiency of oil spill containment booms, skimmers, and gelling agents can be evaluated with repeated duplication of tests to insure statistically significant results. This method of environmentally safe testing permits the evaluation of equipment under varying marine or freshwater conditions without the cost, time, and uncertainties involved in natural environmental tests. The OHMSETT facility is routinely made available to other government agencies, such as the Coast Guard, Navy, Department of Energy, U.S. Geological Survey, and National Oceanic and Atmospheric Administration, for their oil spill experiments.

The OHMSETT Facility, Leonardo NJ



Pipeline leaks, ruptures, and related accidents account for about 14 percent, by volume, of all oil spilled in the nation. With the development of additional oil and gas fields on the outer continental shelf, pipelines will be the principal means of moving products to shore installations. Accordingly, ORD is evaluating existing techniques for the rapid detection of leaks that allow a pipeline to be shut down before significant quantities of petroleum are spilled.

Sources of US Oil Spills



Dispersants

In recognition of the difficulty of oil containment and removal operations in rough seas, present efforts by the Edison Team are centering on the evaluation of oil dispersing chemicals and their delivery systems for coping with large scale spills. The capabilities for applying dispersants from surface vessels and aircraft at environmentally acceptable concentrations and flow rates are being developed.

Shoreline Cleanup

Even with the most rapid response and the best available control technology, many oil spill incidents result in significant environmental impacts to shorelines. These shorelines include estuarine, ocean, and inland areas which may have considerable recreational, aesthetic, or commercial value. The state-of-the-art for cleanup of oil from shorelines currently requires extensive use of manpower and equipment which, in some cases, can be more environmentally damaging to the shoreline than the oil itself. A promising research area currently being addressed by the Edison team is the application of chemical agents to protect the shoreline area by forming a thin film which prevents the oil from adhering to the beach. These agents are intended to be applied just before the oil slick arrives. As the tide recedes, the oil can then be washed by wave action off the beach and back

into the water where it may be more readily collected and removed.

Fingerprinting

Research supported by ORD's Environmental Research Laboratory (ERL) in Athens, Georgia is enhancing current petroleum identification techniques frequently used to locate sources of spills. Through the use of high resolution gas chromatography and computer analysis, an oil sample can be assigned a unique "fingerprint," or pattern of data, that will distinguish it from other samples. These data can then be compared with fingerprinted samples taken from oil tankers, pipelines, or storage facilities, and a determination can be made as to the sources of the spill. Because of the difficulty of determining whether oil samples are indigenous to a given area, or whether they are present as a result of a spill, this project is designed to improve methods of distinguishing between naturally and artificially occuring petroleum compounds

Aerial Photography

To enforce regulatory standards, the early detection of violations is essential. While it is not practical to monitor the entire United States on a continuous basis, the use of aerial photography and remote sensing technologies offer an effective approach to monitoring environmental stresses. Techniques developed by ORD's Environmental Monitoring and Support Laboratory (EMSL) in Las Vegas, Nevada are frequently used to rapidly detect spills, assist in locating violators, and routinely monitor pipeline and storage facilities. EMSL-Las Vegas annually responds to numerous spills across the nation, providing aerial photographs and other data needed for EPA and Coast Guard spill analysis.

Oil Detection Devices

ORD's Environmental Monitoring and Support Laboratory (EMSL) in Cincinnati, Ohio is developing a device for detecting low concentrations of oil in wastewaters from treatment processes involved in coal liquefaction, shale oil recovery, and petroleum refining. Through the use of liquid chromatography and optical fiber technologies, this device will be capable of identifying petroleum in water at very small concentrations. Such monitoring methods are being developed for new and emerging fossil fuel extraction technologies to help avoid future adverse environmental impacts.

Ecological Impact of Oil

A major ORD program is underway at several labs throughout the country to assess the ecological impacts of petroleum and petroleum products on the environment. The Environmental Research Laboratory (ERL) at Narragansett, Rhode Island is researching the problem of oil in the marine environment in several areas. First, with regards to damage assessment, expertise was provided in the early stages of determining the biological effects of the massive Amoco Cadiz spill in France and again at the subsequent Ocean 250 gasoline spill in local waters. The capability for improved response to oil spills is currently being developed in order to further the state of the art of the measurement of biological change as the result of a spill.

Sublethal Effects

The predominant effort at Narragansett, regarding oil spill research, is a diverse approach to the determination of permissible levels of various petroleum components, as required by the Toxic Substances Control Act (TOSCA). This is being done through the evaluation of a variety of sublethal effects. These effects or responses, i.e., the disruption of such biological processes as normal feeding behavior and reproductive patterns, can be elicited in particular marine organisms under certain conditions by very small amounts of oil. The mechanisms by which sublethal effects are brought about are very complex and poorly understood, and ERL-Narragansett is striving to develop biological data and protocols for chemical analysis that will help elucidate some of these mechanisms.

In addition, the Narragansett lab is conducting research to determine the possible histopathological and mutagenic effects of oil. Carcinogenesis of the reproductive tract and breakdown of connective tissue were found in soft shell clams taken in the vicinity of an oil spill in Maine. Carefully controlled laboratory experiments are being conducted to determine whether these effects are the direct result of the spill. Precisely how petroleum and petroleum compounds affect organisms is not clear at this time. Experiments will continue, and others will be undertaken, particularly in the field of genetic toxicology, to attempt to define and clarify these mechanisms.

Sublethal effects, while perhaps not immediately fatal to a given individual, have a direct bearing on the survival of the species as a whole, and consequently, on the balance of the ecosystem of which it is a member. ERL-Narragansett is developing the use of advanced simulated marine environments or microcosms to study the effects of oil and other organic chemicals on marine ecosystems. The concept of the "persistence limit" of the ecosystem – its ability to return to its former state of equilibrium following a perturbation such as an oil spill – is being evaluated as a means of setting permissible levels of toxic substances in the marine environment.

Mussel Watch

Shellfish such as mussels and oysters when exposed to toxic compounds often store and concentrate these substances in their body tissues, allowing their possible use for pollutant surveillance. This principal is being used by ERL-Narragansett to develop data on several categories of marine pollutants, including petroleum hydrocarbons. The Mussel Watch project, coordinated by the Scripps Institution of Oceanography in La Jolla, California, under contract with ERL-Narragansett, is designed to monitor pollutant levels in U.S. coastal waters by systematically analyzing samples of mussels and oysters taken from one-hundred stations along the Pacific and Atlantic coasts, and Gulf of Mexico. Now completing its third year, the Mussel Watch program is recognized internationally as one of the most promising ongoing marine monitoring efforts. This project will play an increasingly important role in assisting the

EPA in setting congressionally-mandated standards and regulations as techniques for quantifying pollutant concentrations are improved.

Supertanker Leaving Valdez Narrows

Martin Rogers/Woodfin Camp

Alaskan Spills

A series of projects supported by ORD's Environmental Research Laboratory in Corvallis, Oregon is being undertaken to document the effects of oil spills on high-latitude arctic lakes, subarctic coastal intertidal environments, and Alaskan salt marsh communities. Alaska's permafrost areas provide a prime location for studying the biodegradation, cleanup, and mediation of oil spills complicated by temperature extremes. Information derived from these experiments will be especially useful in protecting areas impacted by the development of Alaskan oil resources. Tanker movement through the Northwest Passage has been attempted and is considered impractical at this time. Therefore, oil from Alaska's North Slope oil fields is moved to southern markets at least partially by pipeline. Documenting the potential effects of oil spilled in the terrestrial or freshwater environments is important in the event of pipeline failure.

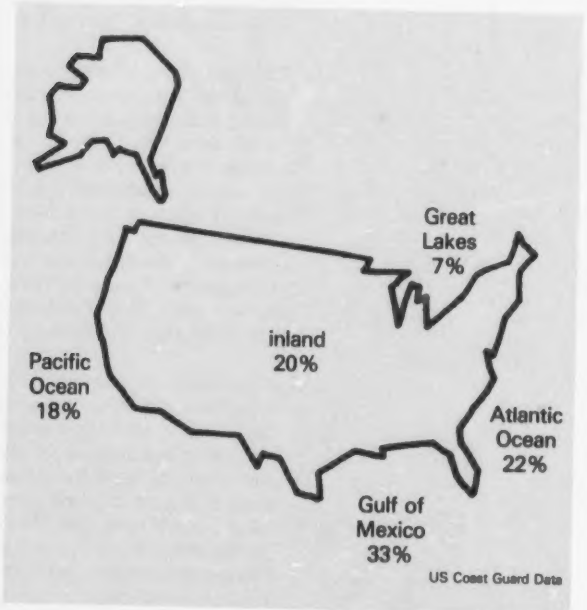
Other research projects being performed at or through ERL-Corvallis are aimed at demonstrating the effects of oil pollution on marine organisms. One project is aimed at assessing the sublethal effects of petroleum constituents on the fatty acid metabolism of fish. Previously, polychlorinated biphenyls (PCB's) had been shown to adversely affect fish fatty acid metabolism causing abnormal biochemical structure of cell

membranes. It is suspected that petroleum constituents may have similar effects. A fish's ability to adapt to temperature changes depends greatly on the chemical makeup of these complex membranes. A second project is directed at determining the effects of selected petroleum refinery effluent components on the growth and population structure of phytoplankton; while a related project is investigating changes in the enzyme activities of fish exposed to sublethal concentrations of these effluents.

Offshore Drilling

ORD's Environmental Research Laboratory in Gulf Breeze, Florida is coordinating several research projects related to offshore oil drilling and the ecological effects of petroleum. Offshore petroleum exploration, extraction, and transportation activities may adversely affect marine ecosystems in the Gulf of Mexico and other coastal areas. Toxicity tests are being performed on various organisms to determine what effects drilling muds and other extraction-related emissions have on the environment. An offshore laboratory, established on a U.S. Naval research platform in the Gulf, is being used by scientists from several universities and the Gulf Breeze lab to study the developmental and behavioral effects of drilling fluids and their components on marine life indigenous to oil and gas drilling sites. In 1977, more than 3500 oil spills were reported in the Gulf area. Research of this kind will be instrumental in setting standards and regulations designed to lessen the impact of pollution associated with offshore oil development.

US Oil Pollution Incidents by Area



Information Transfer

ORD publishes numerous documents related to oil spill research that are distributed to Federal, state, and local governments, academia, industry, and the interested public.

A manual of practice for the environmentally acceptable use of oil spill dispersants will be published in late 1979 by the Edison, New Jersey branch of the Industrial Environmental Research Laboratory in Cincinnati. The manual will include an inventory of available equipment, and a description of the factors that must be considered when using dispersants for spill control and cleanup. The Edison lab is also preparing a "Manual for Oil Spill Cleanup Priorities" to assist cleanup teams as they face decisions regarding aesthetic, commercial, recreational and other environmental aspects of spill cleanup.

Cleanup Manuals

In addition, Edison is preparing a manual for the "Protection, Cleanup, and Restoration of Salt Marshes Endangered by Oil Spills" and a Manual of Practice for the "Protection and Cleanup of Ocean, Estuarine, and Inland Shorelines." Both emphasize the decision-making processes through which field personnel can arrive at effective cleanup recommendations.

Conferences & Workshops

Oil spills in cold climates, such as those in Alaska, are more difficult to deal with than those occurring in warm climates. Aside from the problems of working in sub-zero temperatures, natural ocean cleansing actions are slowed and the oil tends to congeal and even solidify. Accordingly, the Edison lab is preparing a manual on "Cold Climate Oil Spills-Shoreline Restoration and Protection" that will assemble the field methods and techniques proven most efficient in cold climate spill cleanup.

EPA annually sponsors several conferences and workshops throughout the country to promote information transfer both among scientists performing oil spills-related research and the "user community"—design engineers, and state and local officials. For example, a recent workshop in Hartford, Connecticut established response strategies applicable to oil spills emergencies in the New England region, while a similar workshop in Anchorage, Alaska identified scientific needs and capabilities later incorporated into a regional response plan for assessing ecological damage due to major Alaskan spills. Similar workshops have been held for the Gulf of Mexico, Mid-Atlantic, and South Atlantic regions.

Presentations at national and regional conferences for governmental and industrial representatives who deal with spill response and control are prepared by the Environmental Monitoring and Support Laboratory in Las Vegas to disseminate information on aerial monitoring applications. Topics include types of film for different conditions, data collection and processing procedures, and photography analysis techniques. These address oil recognition and differentiation, environmental damage assessment, clean up analysis and potential spill situation recognition.

Individual Research Projects

Selected research projects being performed by or through the laboratory or office indicated:

Industrial Environmental Research Laboratory - Cincinnati OH

(including the Oil and Hazardous Materials Spills Branch, Edison, New Jersey)

- Evaluation of Oil Spill Prevention Practice
- Field Verification of Pollution Control Rationale for Offshore Platforms
- Pollution Assessment of Advanced Oil and Gas Recovery Programs
- Environmental Guidelines for Onshore Impact of Offshore Petroleum Development
- Petroleum Pipeline Leak Detection
- Methods Manual for Oil Spill Source Identification
- Methods of Quantification for Petroleum Oils in Water
- Oil Slick Dispersal Mechanics
- Performance Testing - Inland/Harbor Oil Spill Equipment
- Performance Testing - Offshore Oil Spill Equipment
- Multi-agency Project for Oil Spill Equipment Evaluation
- Manual of Practice for Oil Spill Dispersants
- Manual of Practice for Surface Collecting Agents
- Development and Demonstration of Effective Dispersant Application Techniques
- Manual of Practice for Cold-Climate Shoreline Protection and Restoration
- Surface Treatment Agents for Shoreline and Marsh Area Protection
- Manuals of Practice for Ocean, Estuarine and Inland Shorelines
- Amine Carbamate Gelation for Oil Spill Recovery
- Users Manual for Oil Spill Damage Assessment

Office of Energy, Minerals, and Industry Washington DC

(via Interagency Energy/Environment R&D Program)

- Environmental Assessment of Northern Puget Sound and the Strait of Juan de Fuca (U.S. Department of Commerce - NOAA)
- Environmental Assessment of an Active Oil Field in the Northwestern Gulf of Mexico. (U.S. Department of Commerce - NOAA)
- Major Coastal Ecosystem Characterization and Methodology with Emphasis on Fish and Wildlife as Related to Oil and Gas Development (U.S. Department of the Interior)
- Fate and Effects of Petroleum Hydrocarbons and Selected Toxic Metals in Selected Marine Ecosystems and Organisms (U.S. Department of Commerce - NOAA)
- Energy-Related Water Pollutant Analyses Instrumentation (U.S. Department of Commerce - NOAA)
- Ecological and Physiological/Toxicological Effects of Oil on Birds (U.S. Department of the Interior)
- Ocean Oil Spill Concentration and Trajectory Forecast (U.S. Department of Commerce - NOAA)

Environmental Monitoring and Support Laboratory - Las Vegas NV	• Aerial Remote Sensor Data Collection Processing and Analysis for Environmental Monitoring • Development of Deployable Oil Sensor Package (through interagency agreement with NOAA)
Environmental Monitoring and Support Laboratory - Cincinnati OH	• Production of Water Quality Control Samples for the Quality Assurance Program • Development of Oil in Water Monitor
Environmental Research Laboratory Corvallis OR	• Consequences of Crude Oil Contamination on Cold Climate Salt Marshes and Inshore Ecosystems • Ecological Effects of Oil and Derived Hydrocarbons and Guidelines for Damage Assessment and Methods for Predicting Impact • Alaskan Oil Seeps - Their Chemical and Biological Effects on the Environment • Oil Spills - Effects on Arctic Lake Systems • Effect of Petroleum Hydrocarbons on Fatty Acid Metabolism in Marine Fishes and Possible Sublethal Effect on the Physiology of Temperature Acclimation • Effects of Petroleum Refinery Discharges on West Coast Marine Organisms • Effects of Crude Oil Spills on Benthic/Intertidal Organisms • Evaluation of the Effect of Crude Oil on Permafrost Underlain Ecosystems • Survey of Chemical, Physical, and Biological Conditions Existing in Major Streams Before and After Oilfield Development in the Alaskan Arctic • Response of Microorganisms to Hot Crude Oil Spills on a Subarctic Taiga Soil
Environmental Research Laboratory - Narragansett RI	• Onshore Survey of Macrobenthos Along the Brittany Coast of France, Following the *Amoco Cadiz* Oil Spill • Onshore Biological Survey of the Effects of the *Ocean 250* Gasoline Spill, Fishers Island, New York • Oil Spill Response Research, North Atlantic Coast (Norfolk, Virginia to Eastport, Maine) • Culture of Marine Algae for Experimental Use for the Detection of Toxic Substances and for the Effects of Oil on Reproductive Stages of Marine Macroalgae • Effects of No. 2 Fuel Oil on the Chemically Evoked Feeding Behavior of the Mud Snail, *Illynassa obsoleta* • Effects of No. 2 Fuel Oil on Filter Feeding in Blue Mussels, *Mytilus edulis* • Effects of No. 2 Fuel Oil on the Reproduction of Winter Flounder, *Pseudopleuronectes americanus* • Sublethal Feeding Response of Three Commercially Important Fish Species to Oil-Tainted Prey • Biological Consequences of Exposure of Blue Crabs to No. 2 Fuel Oil • Recovery of Natural Benthic Marine Communities Following Experimental Oiling of Sediments

- Chemical Studies Directed Towards Ecological Damage Assessment of Petroleum Discharges into the Marine Environment
- Relation Between Hydrocarbon Contamination and Tumors in the Soft Shell Clam, *Mya arenaria*
- The Use of Microcosms as a Method for Determining the Persistence Limits of Marine Ecosystems
- Monitoring Levels of Several Classes of Pollutants, Including Petroleum Hydrocarbons, in Mussels and Oysters at Over 100 Stations Nationwide in the *Mussel Watch* Program

Environmental Research Laboratory - Gulf Breeze FL

- Determine Toxicity to Marine Organisms of Petrochemicals and Energy Related Organic Solvents Derived from Offshore Activities and Ocean Dumping
- Toxic, Sublethal and Latent Effects of Selected Petroleum Hydrocarbons and Barium Sulfate on Marine Organisms
- Effects of Petroleum Compounds on Estuarine Fishes
- Environmental Effects of Offshore Drilling and Oil on the Marine Environment (with U.S. Navy)
- Effects of Drilling Fluids and Oil on Corals

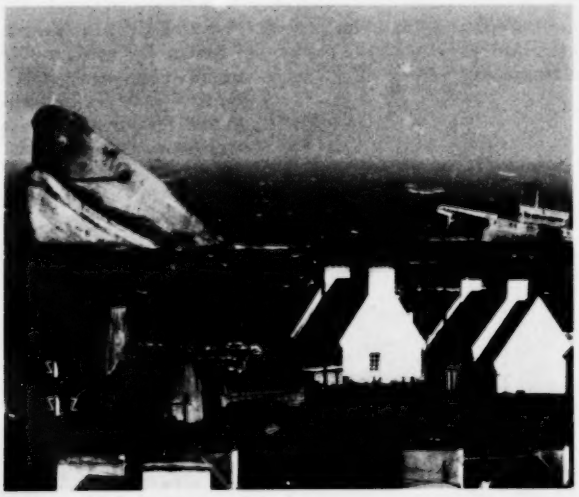
Environmental Research Laboratory - Athens GA

- High-Resolution Separation of Organics in Water (fingerprinting)

Environmental Research Laboratory - Ada OK

- Treatment of Oil Refinery Wastewaters for Reuse Using a Sand Filter-Activated Carbon System

Amoco Cadiz Wreckage



Martin Rogers/Woodfin Camp

Additional Information

For more information, please write to the appropriate sources below:

- **EPA research publications**

  Research Information, RD-674
  Office of Research and Development
  US EPA, Washington DC 20460

- **individual EPA research projects**

  ORDIS, RD-674
  Office of Research and Development
  US EPA, Washington DC 20460

- **EPA conferences and workshops**

  Research Conferences
  Environmental Research Information Center
  26 W. St. Clair Street
  US EPA, Cincinnati OH 45268

- **the Interagency Energy/Environment Research and Development Program**

  Interagency Energy/Environment Program RD-681
  Office of Energy Minerals and Industry
  US EPA, Washington DC 20460

Suggested Reading

- Energy/Environment III. October 1978. EPA-600/9-78-002 Proceedings of the Third National Conference on the Interagency R&D Program. 386 pages.
- Energy/Environment Fact Book. December 1977. EPA-600/9-77-041. 76 pages.
- Alaskan Oil Transportation Issues. October 1977. EPA-600/9-77-019. 11 pages.
- Oil Shale and the Environment. October 1977. EPA-600/9-77-033. 29 pages.
- Who's Who IV in the Interagency Energy/Environment R&D Program. June 1978. EPA-600/9-78-022. 32 pages.
- Research Highlights 1978. December 1978. EPA-600/9-78-040. 70 pages.
- Research Outlook. February 1979. EPA-600/9-79-005. 140 pages.
- Oil Pollution Reports Vol. 5, No. 3 (June 1978 - September 1978). November 1978. EPA-600/7-78-218. (Since July 1974, EPA has published 17 of these quarterly reports. A list of back issues is available from the Oil and Hazardous Materials Spills Branch, U.S. EPA, Edison, N.J. 08817).
- Identification of Components of Energy-Related Wastes and Effluents. January 1978. EPA-600/7-78-004. 524 pages.

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Oil Spills

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